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A simplified method for evaluating swallowing ability and estimating malnutrition risk in older adults
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Abstract:	Objectives: To evaluate the association between malnutrition risk and swallowing ability, determined objectively by tongue strength and subjectively by a newly-developed 4-item questionnaire. Sensitivity analysis was also performed to determine which swallowing indices better estimate malnutrition in older adults. Methods: This cross-sectional study included 60 older adults. The dependent variable was nutritional status evaluated using the Mini-Nutritional Assessment. The independent variables were subjective and objective swallowing ability, evaluated using a 4-item questionnaire of swallowing problems and tongue strength, respectively. Adjusting for covariates, the associations between the two swallowing indices and malnutrition risk were determined using multivariable regression analyses. A cut-off value for low tongue strength was determined using a receiver operating characteristic (ROC) curve, and sensitivity analysis between the swallowing indices and malnutrition risk was performed. Results: Convergent validity of subjective index was revealed by its significant association with objective tongue strength. Based on the highest area under the ROC curve, an 18-kPa cut-off value was chosen to classify low tongue strength. Having a swallowing problem and low tongue strength was significantly associated with malnutrition risk. PPV values of subjective swallowing index was about 1.8-fold higher than objective tongue strength. Conclusions: Self-reported swallowing problems can be used as a subjective index for evaluating swallowing ability in older adults. Subjective swallowing problems and objective tongue strength were associated with malnutrition risk. However, the subjective index better estimated malnutrition risk than the objective index.
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Title page

A simplified method for evaluating swallowing ability and estimating malnutrition risk in older adults

Short title: Swallowing ability and malnutrition risk

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Abstract

Objectives: To evaluate the association between malnutrition risk and swallowing ability, determined objectively by tongue strength and subjectively by a newly-developed 4-item questionnaire. Sensitivity analysis was also performed to determine which swallowing indices better estimate malnutrition in older adults.

Methods: This cross-sectional study included 60 older adults. The dependent variable was nutritional status evaluated using the Mini-Nutritional Assessment. The independent variables were subjective and objective swallowing ability, evaluated using a 4-item questionnaire of swallowing problems and tongue strength, respectively. Adjusting for covariates, the associations between the two swallowing indices and malnutrition risk were determined using multivariable regression analyses. A cut-off value for low tongue strength was determined using a receiver operating characteristic (ROC) curve, and sensitivity analysis between the swallowing indices and malnutrition risk was performed.

Results: Convergent validity of subjective index was revealed by its significant association with objective tongue strength. Based on the highest area under the ROC curve, an 18-kPa cut-off value was chosen to classify low tongue strength. Having a swallowing problem and low tongue strength was significantly associated with malnutrition risk. PPV values of subjective swallowing index was about 1.8-fold higher than objective tongue strength.

Conclusions: Self-reported swallowing problems can be used as a subjective index for evaluating swallowing ability in older adults. Subjective swallowing problems and objective tongue strength were associated with malnutrition risk. However, the subjective index better estimated malnutrition risk than the objective index.

Keywords: Nutritional assessment, Oral function, Swallowing function, Tongue function, Tongue pressure.

Introduction

Oral and general health functionally decline as people age [1]. Gradually declined oral function can lead to oral frailty followed by oral hypofunction. However, they can recover to the healthy stage by early detection and proper dental treatment. Oral health becomes oral frailty when a person has decreased occluding teeth, increased unchewable foods, or slight choking/spillage while eating. Moreover, oral hypofunction is diagnosed when 3 out of 7 oral signs or symptoms are present: oral uncleanness and dryness, reduced occlusal force, reduced chewing function, reduced tongue and lip motor function, as well as reduced tongue pressure and swallowing function [2]. Because eating and swallowing ability plays a major role in oral function, a decline in swallowing ability contributes to malnutrition [3, 4]. Malnutrition increases the risk of morbidity and mortality, and negatively affect the quality of life of older adults [5].

To prevent malnutrition in older adults, early detection of declined swallowing ability is necessary. Several objective and subjective indices have been used to evaluate swallowing ability in older adults. Tongue pressure measurement is commonly used to objectively evaluate swallowing ability, because tongue motor function plays an important role in mastication and swallowing [3, 6]. However, this method requires special instruments and time to perform. To evaluate swallowing ability subjectively, the 10-item Eating Assessment Tool (EAT-10) is commonly used because it is considered a reliable and validated questionnaire [2, 6, 7]. However, some studies reported the limitations of EAT-10 regarding its substantial floor effect,

several redundant items, and relatively low construct validity [8, 9]. Thus, an alternative simple screening method for evaluating swallowing ability should be proposed for the early detection of oral function when a patient is in the frailty or hypofunction stage.

The aim of the present study was to evaluate the association between malnutrition risk and swallowing ability, determined objectively by tongue strength and subjectively by a newly-developed 4-item questionnaire. In addition, sensitivity analysis was performed to determine which swallowing indices better estimate malnutrition in older adults.

Materials and Methods

Study design and participants

The present study was a cross-sectional design. The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2018-112). The participants and their guardians gave written informed consent prior to participating in the study.

The participants were recruited from patients who received dental treatment at the Geriatric and Special Patients Care Clinic, Faculty of Dentistry, Chulalongkorn University during 2017–2019. The exclusion criteria were patients who declined or were unable to perform a tongue pressure test due to severely declined functional or intellectual conditions, or currently had malnutrition. Based on these criteria, 61 older adults aged $\geq$ 60 years old participated in the study.

Power analysis of the sample size was calculated based on the null hypothesis of two independent proportions. The results indicated that the prevalence of malnutrition risk in participants who reported swallowing problem (n_1=7) and those who did not (n_2=54) were 0.71 and 0.11, respectively. Thus, a power of 95.2% was calculated at 5% type I error.

Dependent variables

Nutritional status was measured using the Thai-version of the Mini-Nutritional Assessment (MNA) with a score ranging from 0–30 [10]. The participants were categorized as having malnutrition risk when MNA score = 17–23.5, and being normal when the score ≥24. The MNA was used because it is a standardized and validated instrument in older adults [10].

Independent variables

Swallowing ability was evaluated subjectively by a newly-developed self-reported swallowing problems and objectively by tongue strength. In this study, the subjective swallowing index was a 4-item questionnaire, in which the items were adopted from common signs and symptoms reported by patients with swallowing problems [11]. Swallowing ability was evaluated by interviewing the participants with the assistance of their caregivers, if present. The participants were defined as having a swallowing problem when at least one of the following signs and symptoms was present at least once a week within the past month: 1) having problems swallowing certain food or liquids, or could not swallow at all, 2) coughing or choking when eating or drinking, 3) bringing food back up, sometimes through the nose, or 4) a sensation that food got stuck in the throat or chest. The inter-examiner reliability was determined using 15 patients at the first patients' evaluation visit. The intra-examiner reliability was evaluated by

reinterviewing these 15 patients one week later. The weighted Kappa scores for the inter- and intra-examiner reliability assessments were approximately 0.82 and 0.87, respectively.

The objective swallowing ability was evaluated through tongue pressure, measured using the JMS TPM-02 measurement device (JMS, Inc., Hiroshima, Japan), which consisted of a plastic catheter and a balloon [12-14]. The participants sat in an upright position. The balloon was inserted into their oral cavity and placed on the anterior part of the palate with their lips and jaw closed, while the plastic catheter was held at the midpoint of the central incisors. The participants raised their tongue and pressed the balloon against the hard palate as hard as possible, and the maximum tongue pressure (kPa, kilopascal) was read. This procedure was done in triplicate with 5 min resting intervals, and the tongue strength (kPa) was calculated from the average value of the three measurements. The objective tongue strength was used as a reference to assess the convergent validity of the proposed subjective swallowing index.

Covariates

Information regarding biological factors, oral- and health-related status was recorded. Biological factors were an individuals' age and sex. A dental professional evaluated oral status, comprising the number of remaining functional teeth (ranged from 0 to 28 teeth), number of posterior occluding pairs (ranged from 0 to 8 pairs), and type of denture worn. If more than one type of denture presented, it was classified as the type with a higher number of tooth loss.

Health-related status covered the participants physical and psychological conditions: dependency status and cognitive status, respectively. The clinical frailty scale (CFS) was used to categorize dependency status into independent, semi-dependent, and dependent [15]. Cognitive function was evaluated using the Thai-version of Mini-Mental State Evaluation (MMSE) [16].

With a score ranging from 0–30, the participants were considered as having mild cognitive impairment (MCI) when the score was below 18 and 22 when their educations was at least primary and above primary level, respectively.

Data analysis

Descriptive statistics was performed to determine the percentage (%) and mean ±standard deviation (s.d.). Univariate analyses of the associations between related variables and having a swallowing problem were analyzed using the chi-squared test, whereas its association with tongue strength and MNA score were analyzed using either one-way ANOVA or independent t-test. Variables with p-value < 0.10 were included in the multivariable analyses. Adjusting for covariates, multivariable logistic and linear regression were used to determine the factors associated with the subjective and objective swallowing indices, and their associations with malnutrition risk. A receiver operating characteristic (ROC) curve was plotted to determine the area under the curve (AUC) in the malnutrition risk models; the higher the AUC, the better the model was able to distinguish between the participants with and without malnutrition risk. To categorize the low and high tongue strength, a cut-off value that gave the highest AUC value was chosen. For the sensitivity analysis, the positive predictive value (PPV), negative predictive value (NPV), sensitivity, and specificity between malnutrition risk and the two swallowing ability indices were calculated. The data were analyzed using STATA version 13.0 (StataCorp LP) at a 5% significance level.

Results

The characteristics of the participants based on the subjective and objective swallowing indices, and malnutrition risk are shown in Table 1. The mean ±s.d. age of participants was 78.0 ±7.0 years old. Malnutrition risk was found in 18% of the participants, while the others were within normal limits. MCI was present in 90% of semi- and dependent older participants. Oral status was associated with the subjective and objective swallowing indices, and malnutrition risk. The convergent validity of the subjective swallowing problem was revealed by its significant association with objective tongue strength.

Table 1. Characteristics of the study participants.

Variables	Overall distribution: %	Swallowing ability index		Nutritional status
		Self-reported swallowing problem (Yes): %	Maximum tongue pressure (kPa): mean (±s.d.)	MNA score: mean (±s.d.)
Overall	*100.0*	*11.7*	*25.5 (±10.1)*	*26.0 (±3.0)*
Age (years): 60 – 69	15.0	11.1	34.5 (±8.7)	25.0 (±3.8)
70 – 79	40.0	4.2	26.8 (±9.3)*	26.5 (±2.1)
80 and above	45.0	18.5†	21.4 (±9.4)*	26.0 (±3.3)
Sex: Male	48.3	10.3	27.7 (±9.8)	26.9 (±2.1)
Female	51.7	12.9	23.5 (±10.1)†	25.2 (±3.4)
Health-related status				
Dependency status: Independent	71.7	4.6	27.8 (±9.8)	26.9 (±2.1)
Semi-dependent	18.3	27.3*	19.1 (±8.9)*	25.1 (±2.5)
Dependent	10.0	33.3*	21.2 (±8.8)*	21.1 (±3.9)*
MMSE score: Normal	78.3	6.2	26.5 (±10.4)	26.5 (±2.2)
Mild cognitive impairment	21.7	30.8*	22.1 (±8.6)†	24.1 (±4.4)
Oral status				
Natural teeth: 0	19.7	16.7	24.1 (±10.2)	26.0 (±3.6)
1 - 19	70.5	11.6	25.2 (±9.7)	25.9 (±3.0)
20 and above	9.8	0.0	30.1 (±9.9)	27.0 (±2.0)
Posterior occluding pairs: 0	76.7	13.0	24.5 (±10.2)	26.1 (±3.0)
1 - 3	13.3	12.5	32.4 (±10.7)	25.9 (±1.8)
4 and above	10.0	0.0	26.7 (±9.6)	25.4 (±4.5)
Denture type: No denture	3.3	0.0	30.7 (±1.8)	29.2 (±1.1)
Removable partial denture	45.0	7.4	27.3 (±8.8)	26.0 (±2.7)
Complete denture	51.7	16.1	23.6 (±11.1)	25.8 (±3.2)
Swallowing ability				
Having swallowing problem: No	11.7	-	26.7 (±9.6)	26.0 (±2.8)
Yes	88.3		16.8 (±10.6)*	23.0 (±2.7)*

*p <0.05, †p<0.10. N/A, not applicable due to multicollinearity with dependency status.

OR, odds ratio; β, beta-coefficient; CI, confidence interval; ref, reference.

There were significant associations between the subjective and objective swallowing indices and malnutrition risk after adjusting for potential covariates (Table 2). Because there was collinearity between dependency status and MCI, the MCI variable was not included in the multivariable regression models. Based on the ROC curve, 18 kPa was chosen as a cut-off value to categorize the participants into low and high tongue strength because it gave the highest AUC value when plotting the curve between tongue strength and malnutrition risk (Figure 1).

Table 2. The associations between swallowing indices and related variables.

Variables	Swallowing ability index		Malnutrition risk: adjusted OR (95% CI)	
	Self-reported swallowing problem (Yes): adjusted OR (95% CI)	Maximum tongue pressure (kPa): adjusted β (95% CI)	Model 1	Model 2
Age (years old)	1.05 (0.92, 1.18)	-0.65 (-1.00, -0.30)*	1 (ref)	0.98 (0.84, 1.14)
Sex (Female)	0.55 (0.07, 4.38)	-1.00 (-5.76, 3.76)	6.28 (0.44, 45.4)	3.23 (0.45, 23.4)
Dependency status: Independent	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Semi-dependent	8.44 (0.89.30.1)†	-4.19 (-10.6, 2.28)	0.21 (0.01, 6.26)	0.80 (0.07, 8.65)
Dependent	13.4 (1.24, 39.4)*	-6.67 (-14.1, 1.18)†	22.3 (1.53, 53.3)*	40.6 (3.30, 85.3)*
Swallowing ability measures				
Self-reported swallowing problem (Yes)			35.5 (3.49, 75.5)*	-
Maximum tongue pressure (<18 kPa)			-	0.11 (0.01, 0.71)*
AUC (%)			*88.3*	*74.9*

*p <0.05, †p<0.10. OR, odds ratio; β, beta-coefficient; CI, confidence interval; ref, reference; AUC, Area under the Received Operating Curve (ROC).

Figure 1. Receiver Operating Curves (ROC) and % Area under the ROC curve (AUC) of the association between malnutrition risk and swallowing indices after adjusting for covariates. 1a) Subjective swallowing problem, and 1b) Objective tongue strength (18-kPa cut-off value).
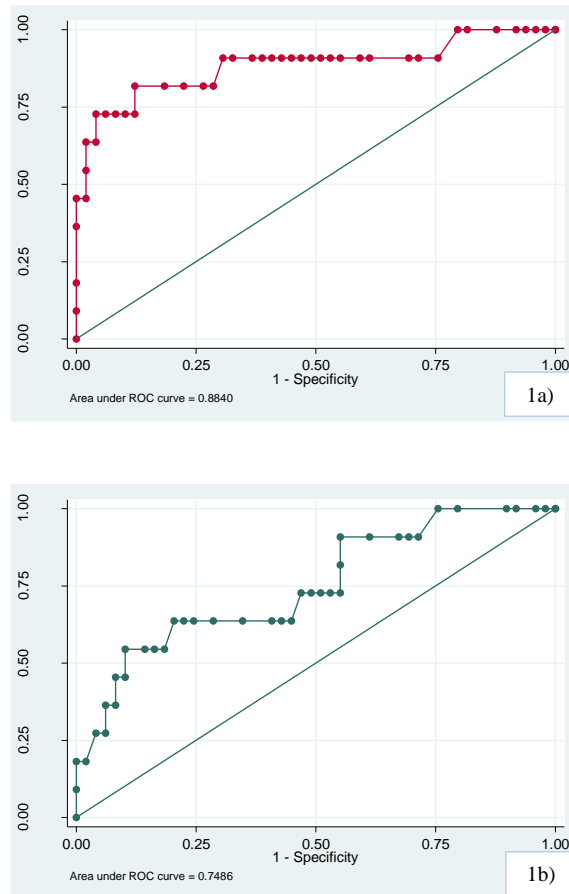
Estimates of the PPV, NPV, sensitivity, and specificity are presented in Table 3. The sensitivity value indicated that 45.5% and 36.4% of older adults having malnutrition risk would have a swallowing problem and lower tongue strength, respectively. The PPV values indicated that the participants with a swallowing problem were 1.5–2 folds more likely to have malnutrition risk than those who had lower tongue strength.

Table 3. PPV, NPV, sensitivity, and specificity (%) between swallowing indices and malnutrition risk.

Impaired swallowing ability	Malnutrition risk: (%)			
	PPV	NPV	Sensitivity	Specificity
Self-reported swallowing problem (Yes)	71.4	87.2	45.5	96.0
Low tongue strength: (< 18 kPa)	40.0	86.0	36.4	87.8

Discussion

The present study developed a 4-item questionnaire as a subjective index to evaluate the swallowing ability in older adults. The convergent validity of the subjective swallowing index was verified using objective tongue pressure as a reference. The findings revealed the association between the subjective and objective swallowing indices and malnutrition risk. Sensitivity analysis demonstrated that the ability of the subjective swallowing index in estimating malnutrition risk was better than objective tongue strength. In this study, the standard EAT-10 was not used as a subjective swallowing index because some of our patients were unable to understand and complete the EAT-10 questionnaire. Due to its complexity and being time-consuming, our study introduced a simplified questionnaire for evaluating swallowing ability in older adults. The questionnaire comprises only 4-item questions with a dichotomous answer, which is simpler than the 10-item questions answered using the 5-point Likert scale in the EAT-10.

Dependent status was significantly associated with low swallowing ability and malnutrition risk. Although the dependency level was associated with advanced age, a higher age was associated with lower tongue strength, but not having a swallowing problem. As supported by previous studies in healthy adults and older people, maximum tongue strength reduced with

advanced age [17-19], which might be due to reduced musculoskeletal function[20] and masticatory muscle strength [17]. These findings imply that dependency status has a greater influence on swallowing ability than chronological age. Therefore, maintaining functional health and being active are important to prevent the progression of oral hypofunction in older adults.

The number of remaining teeth, posterior occlusal support, and denture type were not associated with the subjective or objective swallowing indices. Previous studies found that maximum tongue pressure increased with greater posterior occlusal support assessed using the Eicher index [17, 18]. In the present study, however, all edentulous patients wore a dental prosthesis when performing the tongue strength measurement because most of them required anterior denture teeth to position the pressure bulb. Wearing a dental prosthesis increases the number of posterior occlusal contacts, and therefore, enhances the bite force in edentulous individuals [21]. Individuals with higher occlusal forces present higher masticatory muscle strength [17], which is associated with lower dysphagia risk [12, 22]. Thus, wearing a dental prosthesis might reduce malnutrition risk in edentulous older adults regardless of the remaining functional teeth and posterior occlusal support.

In accordance with previous studies in middle-aged and older adults, malnutrition risk was associated with low tongue strength [3, 23]. To categorize low and high tongue strength, our study chose a cut-off value of 18 kPa because it gave the highest AUC value when plotting the ROC curve. The Japanese Society of Gerodontology suggests using 30 kPa as a cut-off value to diagnose decreased tongue strength [2]. Furthermore, a study in Canadian older adults in long-term care used a value of 26 kPa, the average tongue pressure of the study samples, as the cut-off value to categorize tongue pressure into low and high levels [3]. In our study, however, using either 30- or 26-kPa tongue pressure as a cut-off value gave relatively low sensitivity and PPV in

estimating malnutrition risk. Because the thickness of swallowing muscles might be different among ethnicities [24], individual studies may need to identify the ethnic-specific normal values of tongue strength.

The sensitivity of the subjective and objective swallowing indices in estimating malnutrition risk was comparable. However, the PPV value of the subjective index was about 1.8-fold greater than that of tongue strength. Moreover, the AUC obtained from the subjective swallowing index and malnutrition risk was 15.2% higher than the objective tongue strength value. These findings indicated that the subjective swallowing index might be a more appropriate tool for estimating malnutrition risk in older adults. As supported by earlier studies [11, 25], recognizing signs and symptoms with a thorough history taking is key in early diagnosis and detecting swallowing impairment. Tongue strength measurement could be a supplemental tool to confirm the subjective finding whenever patients or their caregivers have communication problems or are unaware of the symptoms.

Treating oral frailty and oral hypofunction requires a multidisciplinary approach. Thus, dental professionals can be part of a holistic team by early detection of declined swallowing function to prevent the progression into the irreversible dysfunction stage. This study suggests using a simplified 4-item questionnaire as a screening method for evaluating swallowing ability in older adults that do not require an experienced physician in routine dental practice. In addition, we propose a concept for identifying a cut-off value to categorize lower and higher tongue strength using malnutrition risk as an outcome. However, further study in a larger population is required to verify the reliability and validity of the questionnaire. Further use of the simplified questionnaire for early detection of swallowing problem in a clinic and community-based study by caregiver and non-healthcare personnel should be evaluated.

Conclusions

The 4-item self-reported swallowing problems questionnaire was developed as a subjective index for evaluating swallowing ability in older adults. The convergent validity of the subjective index was verified using objective tongue strength as a reference. Both subjective and objective indices were associated with malnutrition risk in older adults. However, the subjective swallowing index better estimated malnutrition risk than the objective tongue strength.

Conflict of interest

The authors declare no potential conflict of interest and no competing interest in this study

Data availability statement

All relevant data are within the paper and its supporting information files.

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Supporting Information

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